molecules, doomed to unending single existence? Can these be changed atoms of some of our well-known elements, a step nearer to the primal elements and with the electrical charge lost? Is it possible for us to bring about these changes? May we not unwittingly have done so at some time or other in the past? Is it possible to restore the electrical charge to such atoms, and so to place them once more on a footing of equality with elements of the conventional type? These and many other questions surge through the mind as one thinks of these wonderful gases. Perhaps the coming century will unfold the answers.

F. P. Venable.

University of North Carolina.

*ENGINEERING EDUCATION AS A PRELIMINARY TRAINING FOR SCIENTIFIC RESEARCH WORK.**

At first thought it might seem that the subject chosen for this address is of such a nature that it should have been made the basis of a paper before the Society for the Promotion of Engineering Education. I admit that it would not have been out of place there, but at the same time I am of the opinion that such an address also forms, as it were, a bridge from our special engineering section to the purposes of the general Association. It will show that the work and the attainments of the engineer form an important and integral part of the scientific work of to-day.

As you no doubt know, there has been for some time general and strong misgivings as to the future of this section of the Association, and many have expressed the opinion that engineers and professors of engineering ought not to belong to the American Association for the Advancement of Science, as the work of the engineer and the pure scientist are of such a very different nature. It must, of course, be granted that the work of most practicing engineers is only distantly related to the work of the members of this Association belonging to the various sections, with the exception of D. But, on the other hand, a great many of the practicing engineers and of the professors of engineering do truly scientific work, and, what is more, in the opinion of the speaker, the preliminary training of the engineer is perhaps the best yet found to educate a man for future scientific research work.

These facts have led the speaker to believe that a consideration of the subject announced might perhaps increase the interest in Section D, and possibly thereby help to prevent its disappearance, which, to many of us, has seemed both imminent and deplorable.

Presumably our friends, the pure scientists, will shake their heads significantly when they read the title of this address, and if any of them should happen to hear it, or later read it, they might perhaps even go so far as to bestow a smile of pity on us poor engineers, etc., who have such a high opinion of our own worth. But even if none of our scientific brethren should be converted, the speaker would feel satisfied with the results should he succeed in giving more confidence to the members of the engineering profession in its broad sense as possessing the necessary training for accurate and important scientific research work.

The proposition which I expect to defend in this address is that engineering education as furnished in the best technical schools of the world, together with the training obtained later in life as a practicing engineer, probably furnishes the best preliminary preparation for the successful prosecution of scientific research work. I am now speaking of the preliminary training; the special knowledge of the subject in which the research work is to be done

* Address of the Vice-President before the Section of Mechanical Science and Engineering, American Association for the Advancement of Science, 1899.

must of necessity be acquired in addition to this engineering education, except when such work is in some one of the engineering branches. I desire also to call your attention to the fact that I do not mean to say that it is the only true method to gain the desired end, but that I have the feeling that, although all roads lead to Rome, yet this one is perhaps the most direct and possibly the best paved.

The object of scientific research work is, as I understand it, to ascertain the facts of nature, to correlate these facts, and finally to deduce the laws of nature as illustrated by the facts discovered. It is probable that a better definition might be given, but for the purpose of this address it is desirable that the various objects of scientific research work be given in something like the form above, and I feel very confident that the definition is one against which no serious objection can be raised. It will be noticed that I divide scientific research work into three parts, and I am sure that everybody will agree when I say that most of the scientific work done to-day is along the first line. The work of correlating the facts discovered is less common, and drawing conclusions from the facts thus correlated by establishing the laws of nature is of such a character that but few scientific workers get so far. That this is the case is but natural, because of the difficulties of the problem, and, although it is the most important of all scientific research work, yet, even of those who work in this special line, there are but few who are able to draw the correct conclusions, and this because of the lack of proper judgment in weighing the importance of supposed evidence and facts, or because of lack of previous training in suppressing the natural tendency to overestimate the value of one's own labor. I take it for granted that everybody appreciates the difficulties and failings which, because of the previous preparation, or, perhaps better, because of the lack of previous preparation, necessarily attach to the scientific research work of to-day. An inquiry into the necessary and desirable qualifications for a man working in this line will, I think, most rapidly lead us to the heart of the question raised in this address: Is not engineering education a remedy for a good many of the weaknesses found in the ordinary scientific man?

These qualifications will here be given separately as effecting the three kinds of work into which I have divided all scientific research work: First, what should be the previous training of a man who is to ascertain the facts of nature? He must necessarily have his faculties of observation trained to the highest degree, so that he sees the facts as they actually are, and, perhaps more important yet, that he can see the single fact which he is looking for, without being disturbed by surroundings which, in the eyes of the untrained man, would obscure the perhaps small objects for which the investigator is looking. It is also very necessary that the observer should be able accurately to describe the object, or fact seen. His mental habit should be such that accuracy is a necessity. And, finally, I think that the scientific worker should, for many kinds of observation, have his hands trained in such a manner that necessary apparatus can be used intelligently and even designed and made.

Second, what are the special qualifications for collecting and correlating the isolated facts of nature, as discovered by others? It seems to me that if anybody is to do this successfully he must possess all the qualifications of a worker in the first line, except that possibly he does not need the manual dexterity which is required by the original investigator. In order properly to classify the facts according to already existing rules and laws, he must also be familiar with the methods by which the

facts have been gathered, in order that he may be able to judge whether the results obtained by original investigators are really facts or only delusions. This man must, therefore, necessarily have a wider experience and outlook than the first observer, and he must possess a sharper judgment, which can only be obtained by special training.

Third, the scientific man who, from a large amount of material collected and correlated by others, shall be able to draw correct conclusions, so as to establish the laws of nature must necessarily have very special qualifications. He must not only have a wide outlook and a profound learning in his special branch; he must in addition be sober-minded, must be able to weigh evidence as thoroughly and impartially as the best qualified judge, and must not only see clearly, but be able to 'go behind the returns' so as to be in a position to decide whether the evidence presented is relevant to the case in question and if it be, whether it really represents facts. Having sifted the evidence, he must be capable of so surveying the field that the general law of which the isolated facts are exponents will reveal itself to his mind. For this latter purpose and to prevent visionary conclusions, I take it that a rigid training in accuracy and sobriety is required.

It is my contention that a man who has received a thorough engineering education, and perhaps has added a few years of professional work to scholastic training, is as well prepared to take up scientific research work as anyone coming from our universities and colleges. I do not think that anyone will deny that the work which is required of the engineering student in our best colleges tends very largely to establish a habit of accuracy, which, as was pointed out before, is one of the most essential qualifications of a scientific man. There is no study like mathematics, with its various applications, to teach a man accuracy; and, as this study forms the backbone in all engineering courses, it is only to be expected that the engineering student, when he leaves college, shall have acquired a habit of mind which makes it impossible for him to be inaccurate, either in his work or in his mode of expression. It is also my belief that the study of mathematics teaches truthfulness and sobriety of thought. As was explained before, the latter I deem one of the most essential qualifications for the man who is to do the highest grade of scientific work. Engineering education and the practice of the engineering profession will necessarily teach this sobriety of thinking more thoroughly than any other kind of education. The object of the engineering professions is to utilize the laws and forces of nature for the well-being of the human race. Consequently the engineer must build upon the laws of nature, must apply them, and the results of such application we see in the innumerable achievements of the engineer of modern times. The true engineer first surveys the field, then makes his plans and computations, based upon his observations and upon the laws of nature; the result of such work is, for instance, either the machine which is to do a certain work or the bridge which is to carry the modern heavy railway train, or it may be one of those monster buildings which within the last few years have been erected in the large cities. If the preliminary work of the engineer has not been accurate, or if he has not applied the laws of nature correctly, the result is inevitable; the machine will not do its work, the bridge will not carry the train, or the tall edifice building will not carry the enormous weight concentrated in it. The punishment will follow the mistake of the engineer as surely as the earth keeps on moving around the sun. This is the

great point in engineering education which, at any rate in some respects, makes it the best preliminary training for men who are to do scientific research work. A good engineer is necessarily an accurate man; he is necessarily also a soberly thinking man, and, thirdly, he must also possess a discriminating judgment, as the results which follow superficial reasoning or visionary planning are fatal to all engineering work. There are no studies which teach this lesson so strongly as the various professional engineering studies, and it seems to me, therefore, that one of the most essential qualifications for doing thorough scientific work is obtained in a higher degree by engineering education than by any other training. It is true that the ordinary engineering student has but limited opportunity to test his plans and computations in actual practice. But it must be remembered that the student is always reminded of the inevitable results of even one false step in the class-room, laboratory and draughting room, and that his work is controlled by men who are supposed to have had the necessary experience in practical life. That the actual practice of the engineering profession is the best teacher in this line need hardly be stated. The work of the engineering student in the draughting room, in the shop and in the laboratory fits him peculiarly for scientific research work, as he there gains the necessary dexterity of his hands, his powers of observation are being trained, and he learns to be accurate and neat. The only objection which perhaps might be raised against my contention is that the engineering courses of study are narrow in their nature, and consequently that the graduate of an engineering college will be a narrow man. It is true that in a certain sense the course of study is narrow; it does not include any classics, for instance; nor does it include as much of the humanities as is desirable. But, on the other hand, specialization has gone so far in the present day that I think I am correct when I state that, for instance, the ordinary classical course, with its excessive amount of Greek and Latin, is fully as narrow as the engineering course; and as to the scientific college course it is enough to say that there is no reason why it should be deemed less narrow than the engineering course, except for the fact that specialization has not been carried so far. The ideal engineering education is first an academic course, followed by two or three years' work in the engineering college, and if such length of time of study is not deemed too much for the profession of a lawyer there is no reason why it should be too long for the engineer. A man educated as just indicated would certainly be better fitted for scientific research work than any other college graduate who had an equal amount of time for preparation but had taken no engineering work.

That the engineer of the present day is doing a large amount of scientific research work does not need any proof, and because of his training I am of the opinion that his work is of a better quality than that of the ordinary scientific man; more reliance can be placed on it, as it necessarily has had to undergo a more severe test, both for accuracy and soundness in conclusion, than if it had been done by a person who had not had the preliminary training of an engineer.

To disprove this statement I suppose that some one might very likely mention the name of Kreidler, or perhaps even that of Kelley, but it is sufficient to state that these men are not, nor were they ever engineers, and it might also be pointed out that engineers are not responsible for any of the perpetual motions which, even in this enlightened day, seem to be as numerous as they ever were.

In conclusion, I desire to repeat that we engineers, or semi-engineers, need to feel

that our work is very often scientific research work of the highest character, and that although we are very often told that because of its practical nature it does not belong to pure science, yet we should insist that, whether it be pure science or not, it is scientific work, and because of our previous training is likely to be of permanent value.

I desire, finally, to offer an apology for the shortcomings probably altogether too visible in this address, and to express the hope that Section D of the American Association for the Advancement of Science, because of the large and important field which it represents, will start in on a new era of prosperity.

Storm Bull.

University of Wisconsin.

FAUNA AND FLORA OF PUERTO RICO.

In the past the island of Puerto Rico was densely populated. Before Columbus discovered America and Ponce made his first European settlement on the island there had been two races on it, and each had occupied practically the whole of it. The first was, to judge by its shell heaps and other remains, a people of Northern origin, and the other was of the Carib race. At the time of the occupation by the Spanish the population was, according to their reports, as dense as it is now. It is now the most densely populated rural community proper on the continent of America. It has upwards of 230 inhabitants to the square mile, and this is strictly rural, as it has no great cities, the largest being of less than 40,000 inhabitants. The people generally live in the country, and the country huts are scattered in all sorts of places, expected and unexpected, from the crests of the mountains to the coasts.

Under these conditions only a very small original or wild fauna can be expected. Generally speaking, the largest wild mammal is a ground squirrel, about the size of a gopher. A few others of larger size are reported from time to time, but they are only occasional and are probably animals escaped from cultivation. Probably the larger animals once existed, and their traces could doubtless be found by a linguist in the place names which abound all over the island and are quite often not Spanish, but these creatures have been so long gone that they are not even mentioned by the natives, nor do the customary traditions otherwise refer to them.

The largest bird on land is the pretty white heron, of about the same size as the common heron of the Northern States. It belongs in the swamps. The nightingale is not rare, and sometimes in winter some of the Northern songbirds are seen, but in general the avian fauna is very sparse. The song and twitter of the birds is very rarely heard. Along the coasts the pelican, large and clumsy looking, except on the water, is very common where it is very much occupied with its profession of fisherman. It prefers protected harbors to the open water outside, and shows no greater shyness of man than to keep in the less disturbed waters of the ports.

The most common quadruped, by all odds, is the little lizard or swift, which can be seen almost anywhere in the sun and even frequently penetrates houses and lives with the family. They are very quick, intelligent, cleanly creatures and are only dangerous to cockroaches, flies and other small vermin. The largest land reptile is a snake, which sometimes reaches six or eight feet in length, something like the black snake, but called a python. It does no harm, so far as learned. There are a few other species of less size whose venom is not yet proved and is not feared by the natives.

The land crabs, snails and other such creatures are far from common, except in marshy places and near the coast. The